Forest Research
Extension Note
Vancouver Forest Region
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EN-019 Silviculture March 2003

KEYWORDS:

red alder, hardwood, seedling growth, growth response, fertilization, phosphorus, silviculture

CITATION:

Brown, K.R and P.J. Courtin. 2003. *Effects of Phosphorus Fertilization on the Early Growth of Red Alder Plantations.* Research Section, Vancouver Forest Region, BCMOF. Nanaimo, BC. Extension Note EN-019.

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BRITISH COLUMBIA

Effects of Phosphorus Fertilization on the Early Growth of Red Alder Plantations

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INTRODUCTION

Red alder (*Alnus rubra* Bong.) is the most widespread hardwood tree species in low-elevation forests of coastal British Columbia. Alder is becoming increasingly important for making valuable wood products. Consequently, the potential of spacing and pruning early in stand development to enhance log quality and growth has been examined (Courtin et al. 2002).

Alder has rapid juvenile growth rates (Harrington 1990), may improve site nitrogen (N) capital through atmospheric N_2 fixation (Binkley et al. 1994), and is immune to laminated root rot (*Phellinus weirii*) (Thies and Sturrock 1995). Low-elevation, moist, and nutrient-rich ecosystems offer the greatest growth potential for alder. However, its immunity to *Phellinus* may also make red alder an appropriate species to plant on sites that are less moist and fertile.

The growth of red alder on eastern Vancouver Island may be limited by low availabilities of phosphorus (P). When seedlings were fertilized with P (but not other elements) within a year of planting, tree volumes increased by up to 96% over three years (Brown 1999; Brown unpublished[1]). A low P supply may limit N_2 fixation (Ribet and Drevon 1997) and the effects of P addition on growth may be enhanced under mild moisture stress (Radwan and DeBell 1994). Phosphorus deficiencies may also affect rates of litter decomposition (Compton and Cole 1998), thereby influencing rates of N and carbon accumulation in soil. Therefore, on drier sites of eastern Vancouver Island, management of P supply may be important for maintaining growth of alder as well as for managing N availability to coniferous species.

Alder fertilization trials conducted on Vancouver Island (Brown 1999) employed a single-tree plot design. This is useful for identifying which elements limit growth, and for demonstrating short-term growth responses. However, larger multi-tree plots are needed to assess the effects of nutrient additions on long-term stand-level growth and yield, and on ecosystem properties related to accumulation and cycling of soil N and carbon.

In 1999, we established a field experiment designed to assess the long-term effects of varied P supply on the growth, stand development, and soil of a young alder plantation on eastern Vancouver Island. Here we report growth responses of planted alder through the first two growing seasons.

TRIAL AREA

The study site is in the very dry maritime subzone of the coastal western hemlock biogeoclimatic zone (CWHxm, site series 01/05) (Green and Klinka 1994), near Bowser on eastern Vancouver Island (49 25' N, 124 40'W).

[1] K.R. Brown. 2003. *Three-Year Growth Responses of Young Red Alder on Vancouver Island to Fertilization.* K.R. Brown and Associates. Victoria, BC. Unpublished manuscript.

It is adjacent to a young alder plantation which had previously responded to fertilization with P and other elements in 1997 (Brown 1999).

Coarse fragment contents averaged 60%; soil texture was sandy loam. Soil chemistry (0–30 cm depth) is summarized in Table 1. Values are typical for young red alder plantations (Brown unpublished[2]; Compton et al. 1997)

The site previously contained a *Phellinus weirii*-infected Douglas-fir stand that had been harvested in 1998. Following harvesting, the site was stumped in preparation for planting Douglas-fir. However, only one portion of the block was planted with Douglas-fir, and the other with alder seedlings (stock type 415-plug), in fall 1999. Survival was patchy and the site was fill-planted in April 2001 with stock type 310 0.5+0.5 seedlings to a target density of 1300 seedlings ha^{-1}.

PLOT LAYOUT

Fifteen plots, each 45x45 m, were laid out in March 2001. Each plot consisted of a 25x25-m inner measurement plot plus a 10-m treated buffer, and was separated from adjacent plots by an untreated buffer (Figure 1). Three plots each contained one Douglas-fir wildlife tree. Seedlings were counted and plots were fill-planted to ensure a minimum of 81 seedlings/measurement plot. Seedlings were tagged, and heights and basal diameters were measured. Locations of all trees were mapped for all plots. In total, there were 936 measurement trees planted in fall 1999 and 426 planted in spring 2001.

For soil chemistry determinations, two sample points were randomly located along each diagonal running from the plot center to the corner post of the measurement plot. The eight samples from each plot were then composited and analyzed. Exchangeable cation contents were determined by inductively coupled argon plasma (ICAP) emission spectrometry following extraction in $BaCl_2$; extractable P was determined by autoanalyzer.

Table 1. Soil elemental concentrations (0–30 cm, n=5), by treatment.

Measure	Mean	(s.e.)
Bray-P (mg kg^{-1})	10.7	(1.3)
N (g kg^{-1})	1.5	(0.1)
Min. N (mg kg^{-1})	19.8	(1.7)
C (g kg^{-1})	32.0	(2.5)
Cation exchange capacity	3.67	(0.37)
Exchangeable Al (cmol kg^{-1})	0.64	(0.08)
Exchangeable Ca (cmol kg^{-1})	2.46	(0.27)
Exchangeable K (cmol kg^{-1})	0.07	(0.01)
Exchangeable Mg (cmol kg^{-1})	0.42	(0.05)
pH (H_2O)	5.3	(0.1)

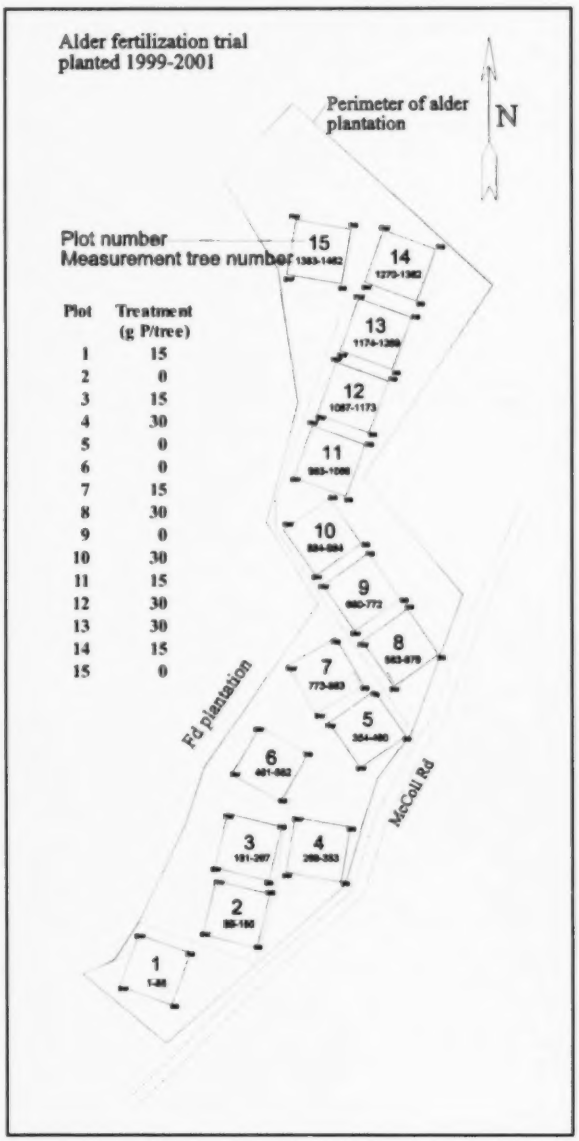

Figure 1. Map of the study site.

[2] See Footnote 1.

TREATMENTS

The long-term objective of the treatments is to maintain differing levels of plot P status, while maintaining adequate concentrations of other elements. In May 2001, P was applied as triple super phosphate (TSP, 0-45-0) at rates of 0, 15, or 30 g P tree^{-1}. These are rates which induced a range of growth rates and foliar P concentrations in previous studies (Brown 1999)[3]. Treatments were randomly assigned to plots. P was applied at 20 cm depth in two planting holes located 15 cm from, and on either side of, each seedling. Enough vegetation was removed from the area around each seedling to allow placement of fertilizer.

MEASUREMENTS

In August 2001, newly matured foliage was sampled from the stem and top-most main lateral branch from 20 randomly selected measurement trees in each plot. Stem and branch leaves were composited by plot, oven-dried, crushed and ground, and analyzed for elemental concentrations. Foliar P concentrations determined in 2001 were used to guide the second addition of P (15 g tree^{-1}) to the high-P plots in March 2002.

Stem basal diameters and heights were measured following the 2001 and 2002 growing seasons. Stem volumes were calculated as $V=\pi r^2 h/3$. Growth data were analyzed by analysis of covariance for a completely randomized design.

RESULTS AND DISCUSSION

Survival was very good. Less than 1% of the measurement trees planted in 1999 died during 2001 and 2002; 6% of the measurement trees planted in 2001 died during 2001 and 2002. Higher mortality in the 2001 trees probably resulted from the inclusion of first-year seedlings (15/26 died during Year 1) and because some fill-planting was required in poorer quality microsites. Mortality appeared more frequent around Douglas-fir leave trees.

Growth increased with P availability. The size of 1999 trees, measured in April 2001 (prior to fertilization), varied with plot and with soil P concentration (Figure 2). Average soil P concentrations on the site were indicative of P-limited alder soils (Harrington and Courtin 1994; Brown unpublished[4]). Unfertilized seedlings grew well through 2002, with average heights of 2.9 m for seedlings planted in fall 1999 and 1.6 m for seedlings planted in spring 2001. Nonetheless, P additions increased tree volumes by up to 58% for seedlings planted in fall 1999 and by 145% for seedlings planted in spring 2001 (Figure 3). These responses were consistent with those reported previously (Brown 1999).

Increased volumes were due more to increases in diameter than in height, although both increased. This is a response often observed following fertilization. Older trees have, to-date, responded more to the high-P treatment, probably because their P requirements were greater and they were relatively more limited by soil P supply. Relative increases in basal diameter were greater through two years than through one; for the seedlings planted in 2001, relative increases in height were also greater in the second year.

Foliar concentrations of P in unfertilized alder appeared deficient (Brown 2002), and P additions increased foliar concentrations of N, P, K, Ca, S, Fe, and Cu (Table 2). Given these growth and nutritional responses to added P, we conclude that P deficiencies limit the growth of red alder on this site.

CONCLUSIONS

Growth of red alder increased over two growing seasons, when fertilized with P within one growing season after planting. Volumes increased by 145% in trees fertilized within one month of planting, and up to 58% in trees fertilized 1.5 years after planting. Basal diameters have responded more to P additions than have heights. The responses to date are consistent with results from earlier screening trials (Brown 1999; Brown unpublished[5]). While responses are promising, we do not yet know the longer-term effects of P fertilization so soon after planting and consequently cannot yet recommend it in practice.

Some possible longer-term effects of increased P availability on tree growth, stand development, and ecosystem properties include:

1. Increased branching (Brown 2002; Brown unpublished[6]). If so, log quality, expressed as the amount of clear wood, may decrease as growth rate increases, unless lower branches are pruned.

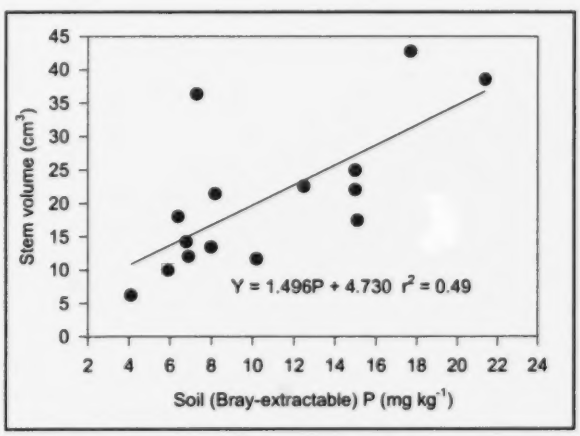

Figure 2. First-year volume growth of unfertilized red alder in relation to soil Bray-P levels. Each point represents the mean individual tree volume and Bray-P level for a given plot.

[3] The amount of P typically added at planting to conifers in coastal BC is <3 g.

[4, 5, 6] See Footnote 1.

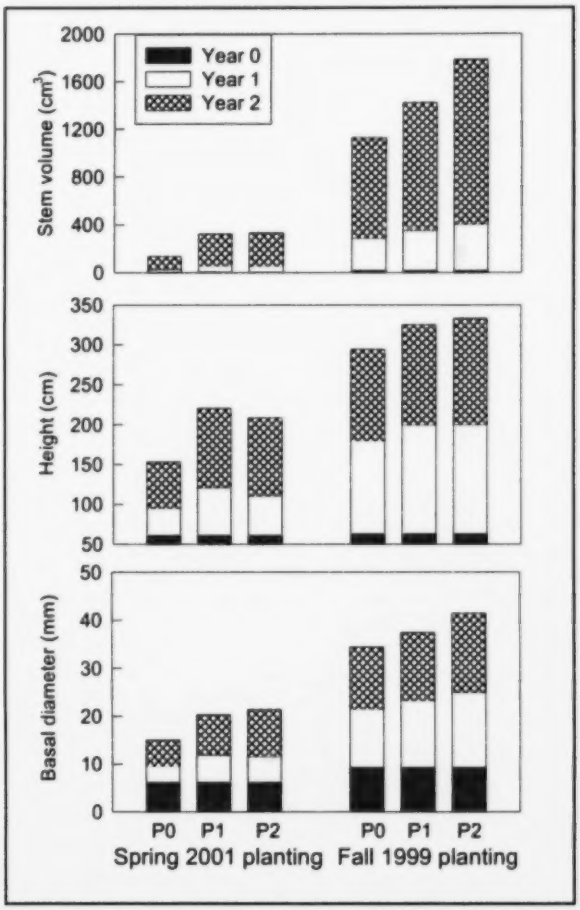

Figure 3. Stem volume, height, and basal diameter growth over two growing seasons, for seedlings planted in fall 1999 or spring 2001 and fertilized in spring 2001. The black portion of each bar shows average size of seedlings prior to fertilization. The white and cross-hatched portions show adjusted mean sizes at the end of Years 1 and 2, respectively, minus average size at the end of the previous year.

2. Changes in mycorrhizal abundance and diversity.

3. Increased rates of N_2-fixation and litter production, which, in turn, might lead to greater accumulation of soil N and carbon. However, this may be offset by increased rates of carbon and N mineralization.

4. Faster growth and a reduced time to canopy closure for the red alder could lead to earlier mortality of subdominant trees, perhaps though moisture stress. Conversely, improved P nutrition may increase red alder's efficiency of water use and its resistance to moisture stress, as shown for hybrid poplar (Harvey and van den Driessche 1997). If so, stockability of the site (Harms et al. 1994) might be increased.

Assessment of the above responses over time will provide useful insight into the long-term costs and benefits of fertilizing young red alder.

ACKNOWLEDGEMENTS

We thank Peter Poland with the South Island District of the BC Ministry of Forests, and Mike Steeves of Steeves Forest Consulting Ltd., for facilitating our use of the site for this research. Richard Towers, Tom Collinson, David Robinson, and Peter Fielder assisted in plot establishment, fertilization, stem mapping, soil and foliar sampling, and tree measurements. Nutrient analyses were conducted by the BC Ministry of Forests analytical lab staff, supervised by Clive Dawson. Funding was provided by grants from Forest Renewal BC and Forestry Innovation Investment.

REFERENCES

Binkley, D.; K. Cromrack Jr.; and D.D. Baker. 1994. "Nitrogen Fixation by Red Alder: Biology, Rates, and Controls" pp 216–228 in *The Biology and Management of Red Alder*. D.E. Hibbs, D.S. DeBell, and R.F. Tarrant (editors). Oregon State University Press, Corvallis, OR.

Brown, K.R. 1999. *First-Year Growth Responses of Young Red Alder Stands to Fertilization*. Research Branch, BC Ministry of Forests. Victoria. Extension Note 36.

Table 2. Mean elemental concentrations in first order (branch) foliage, collected in August 2001.

	Concentration										
P level	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	S (g kg^{-1})	Fe (mg kg^{-1})	B (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
P0	29.7	1.5	5.5	6.2	2.6	1.7	72	14	11	37	247
P1	32.1	2.0	5.8	6.8	2.5	1.7	81	13	11	32	312
P2	32.7	2.0	6.0	6.7	2.6	1.8	95	15	11	31	303

———. 2002. "Effects of phosphorus additions on growth, mineral nutrition, and gas exchange of red alder (*Alnus rubra*) seedlings grown in outdoor sandbeds" in *Western Journal of Applied Forestry* 17:209–215.

Compton, J.E. and D.W. Cole. 1998. "Phosphorus cycling and soil P fractions in Douglas-fir and red alder stands" in *Forest Ecology and Management* 110:101–112

Compton, J.E.; D.W. Cole; and P.S. Homann. 1997. "Leaf element concentrations and soil properties in first- and second-rotation stands of red alder (*Alnus rubra*)" in *Canadian Journal of Forest Research* 27:662–666.

Courtin, P.J.; K.R. Brown; and G. J. Harper. 2002. *Red Alder Management Trials in the Vancouver Forest Region.* Vancouver Forest Region, BC Ministry of Forests. Nanaimo. Extension Note EN-016.

Green, R. and K. Klinka. 1994. *A Field Guide for Site Identification and Interpretation for the Vancouver Island Forest Region.* Land Management Handbook No. 28. BC Ministry of Forests, Victoria.

Harms, W.R.; D.S. DeBell; and C.D. Whitesell. 1994. "Stand and tree characteristics and stockability in *Pinus taeda* plantations in Hawaii and South Carolina" in *Canadian Journal of Forest Research* (24):511–521.

Harrington, C. 1990. "*Alnus rubra*" pp. 116–123 in *Silvics of North America. Vol. 2. Hardwoods.* R.M. Burns and B.H. Honkala (tech. coord.). USDA. Agriculture Handbook 654.

Harrington, C. and P. Courtin. 1994. "Evaluation of site quality for red alder" pp. 141–158 in *The Biology and Management of Red Alder.* D.E. Hibbs, D.S. DeBell, and R.F. Tarrant (editors). Oregon State University Press, Corvallis, OR.

Harvey, H.P. and R. van den Driessche. 1997. "Nutrition, xylem cavitation, and drought resistance in hybrid poplar" in *Tree Physiology* 17:647–654.

Radwan, M.A. and D.S. DeBell. 1994. "Fertilization and nutrition of red alder" in *The Biology and Management of Red Alder.* D.E. Hibbs, D.S. DeBell, and R.F. Tarrant (editors). Oregon State University Press, Corvallis, OR.

Ribet, J. and J.-J. Drevon 1997. "The phosphorus requirement of N_2-fixing and urea-fed *Acacia mangium*" in *New Phytologist* 132:382–390.

Thies, W.G. and R.N. Sturrock. 1995. *Laminated Root Rot in North America.* Forest Service, USDA. Research Bulletin PNW-GTR-349.